CleanPower Turbinator™
A new low pressure turbine

Produksjonsteknisk Konferanse
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Background CleanPower AS

- Established 2005
- Licensed technology from INPOWER AS
- Axial turbine with integrated generator
- Pilot model installed and og validated in co-operation with Statkraft
- Local ownership
  - NEAS 53,9 %
  - Bølgen Invest 19,5 %
  - Sparebank1 Nordvest 19,5 %
  - Knudtzon Senteret AS 2,9 %
  - Employees 2,5 %
  - Tensa AS 1,8 %

Brunvoll Rim driven thruster (RDT)

Prototype testing in Kristiansund

Hegset dam Turbinator

Hydropower from environmental release

Statkraft
REN ENERGI

The Hegset dam

- Intake to 'Nedre Nea' and 'Hegsetfoss' hydro power stations
- Regulation height: 18 ft
- Dam height: 102 ft
- Reserved flow: 53 cfs (through flood hatch and/or outlet pipe)

Statkraft

Cooperation Statkraft - CleanPower

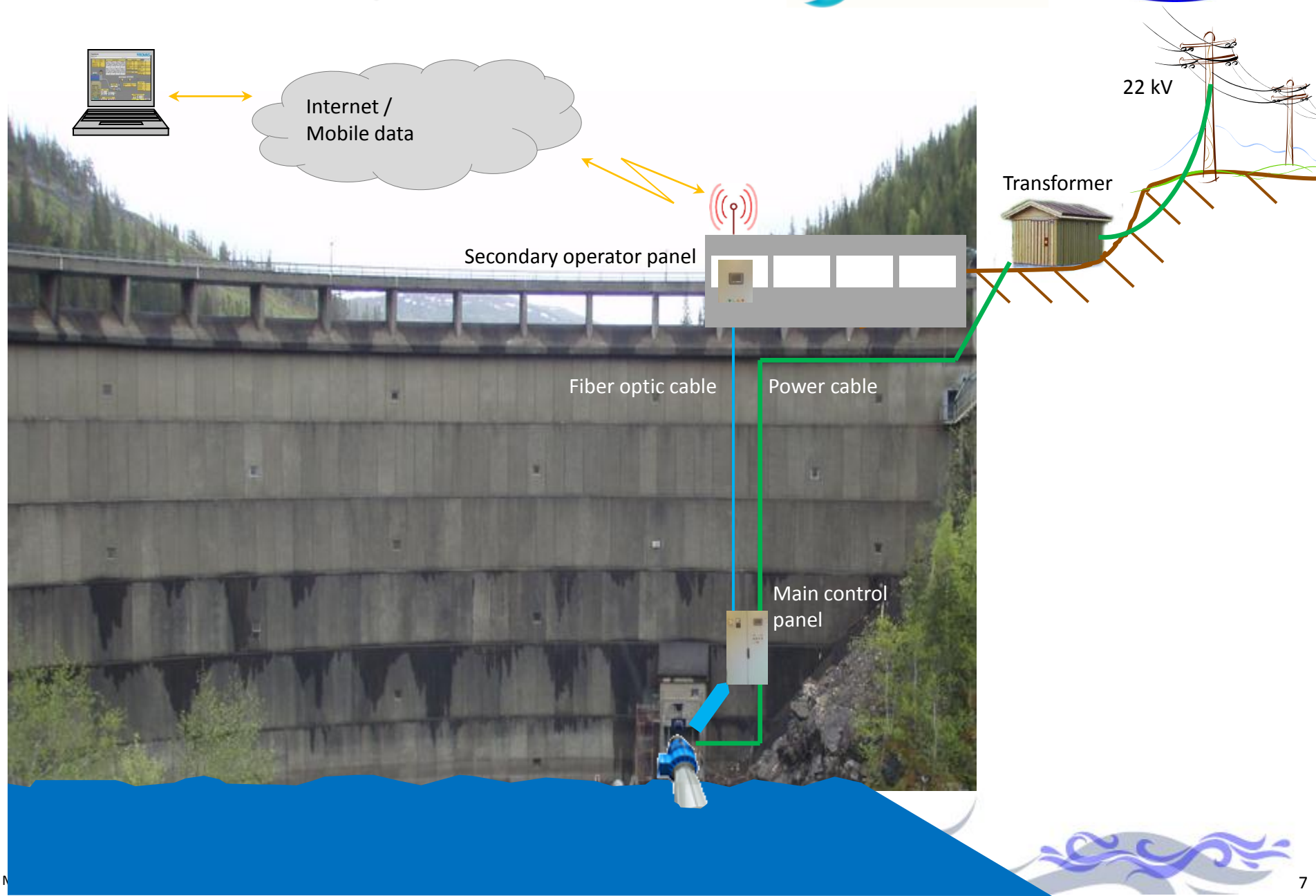
- Project partly funded by 'Innovasjon Norge'
- Installation of CleanPower Turbinator on existing environmental release pipe
- Exploit the reserved flow between May 1st and September 30th.
- Electromechanical package including control and monitoring of the unit, and grid connection.

The mission

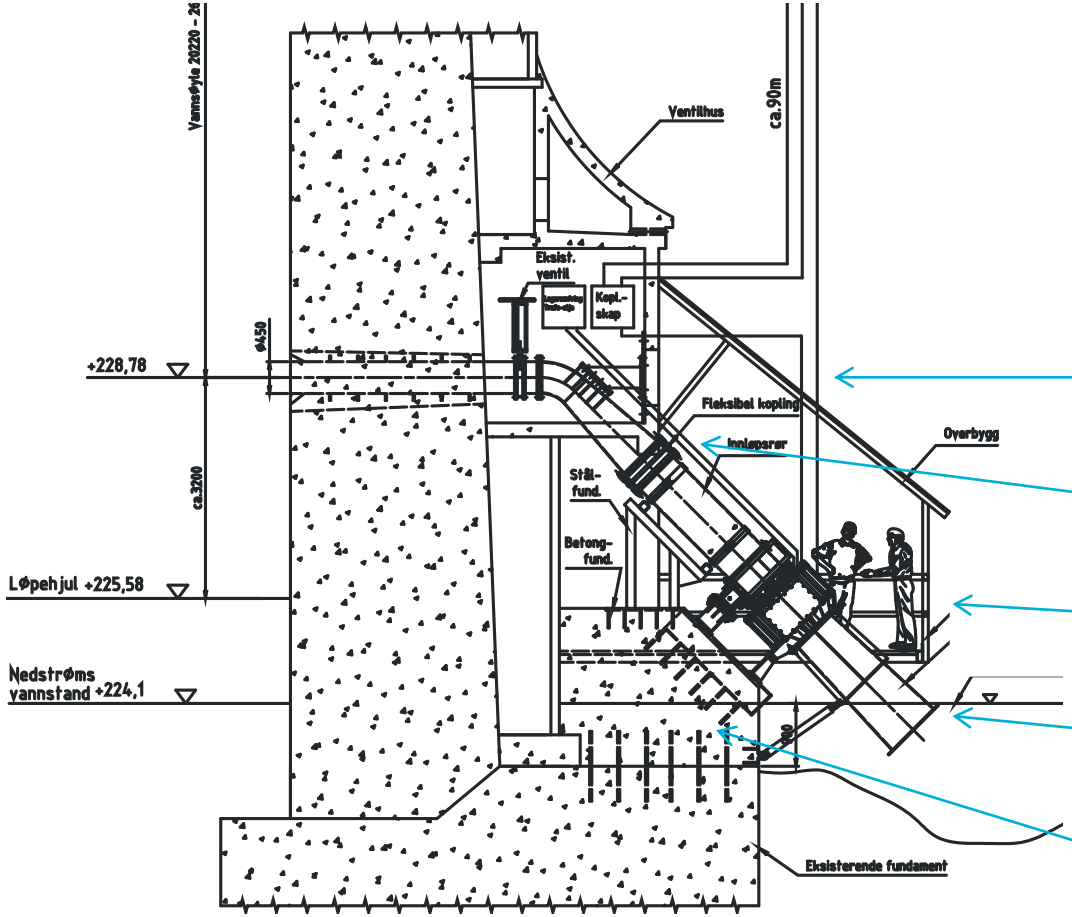
- Maximize the power production given the technical constraints:
  - Nominal flow: 42 cfs
  - Use existing pipe Ø 17.7 in (13 ft pressure loss)
  - Net head: 78 ft

Statkraft

Mission accomplished



Mission accomplished



Valve+ control system

Bend / diffusor

Repos w/protective roof

Draft tube: Straight, conical

Foundation: Concrete w/ steel anchoring

The Hegset dam

First water through the turbine

Lessons learned

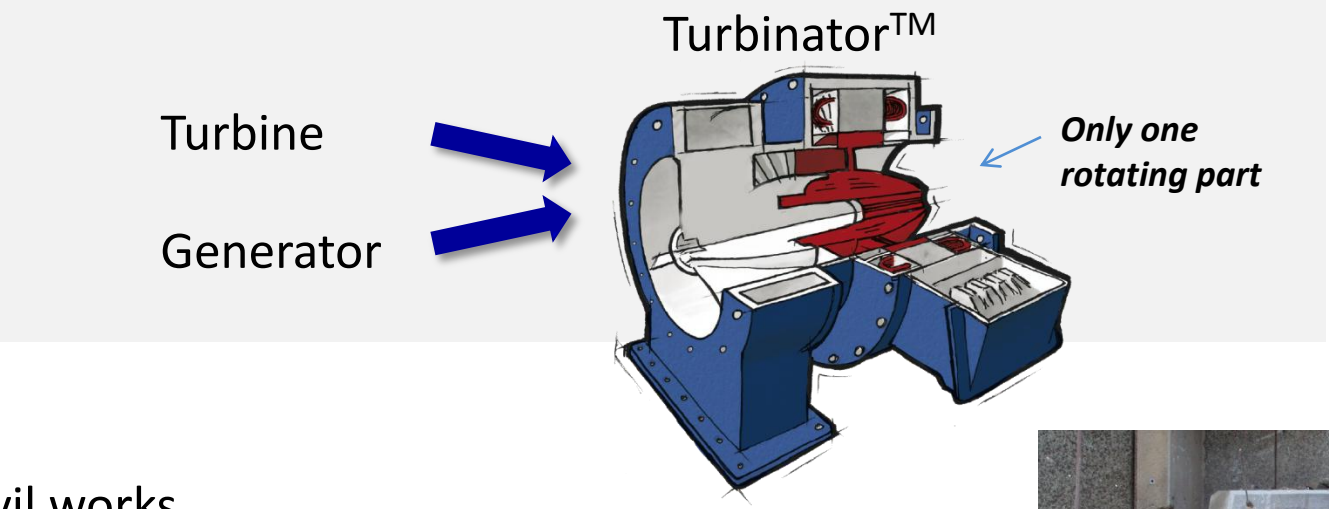
- **There are always minor challenges with new machinery**
  - Turbinator has been running in 2010 og 2011.
    - Max power delivered: 280 kW
    - No electrical problems, no vibration
    - Bearing seals are upgraded to mechanical seals
    - Statkraft will build a better protection around the turbinator during autumn 2012

Major flooding at the Heggset dam, September 2011

Turbinator™ – what is unique?

Robust **machinery**

- Axial flow turbine with fixed blades (single regulated fixed kaplan)
- Permanent magnetized synchronous generator



Easy civil works

- Waterproof machine does not require a power house
- Solid concrete foundation

Reduced civil works → ***Reduced investments***

Easy installation

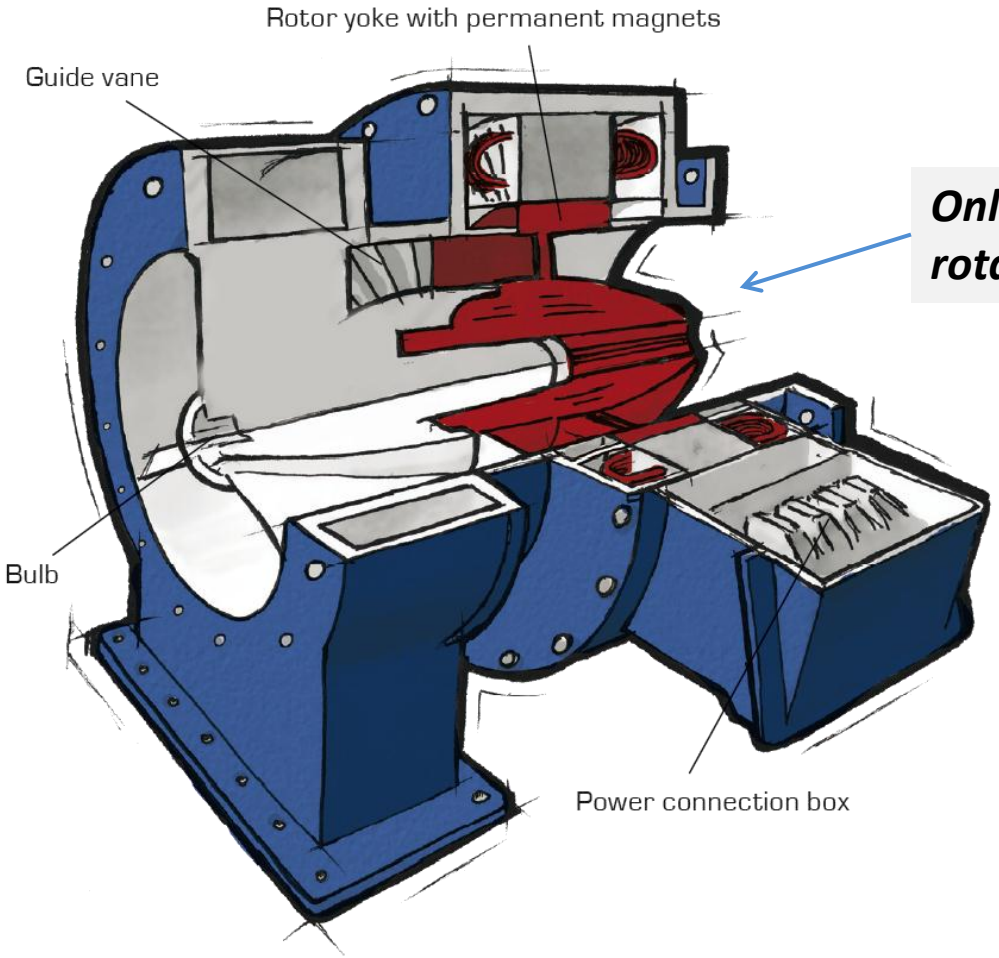
Flange in / flange out

1…

2…

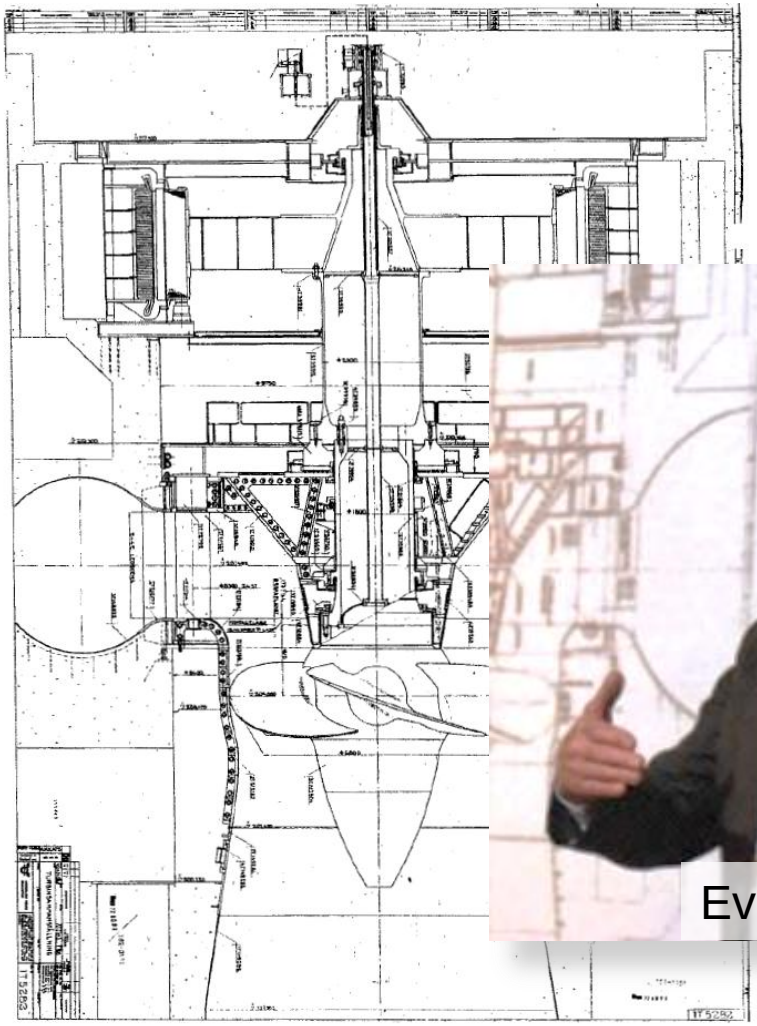
3…!

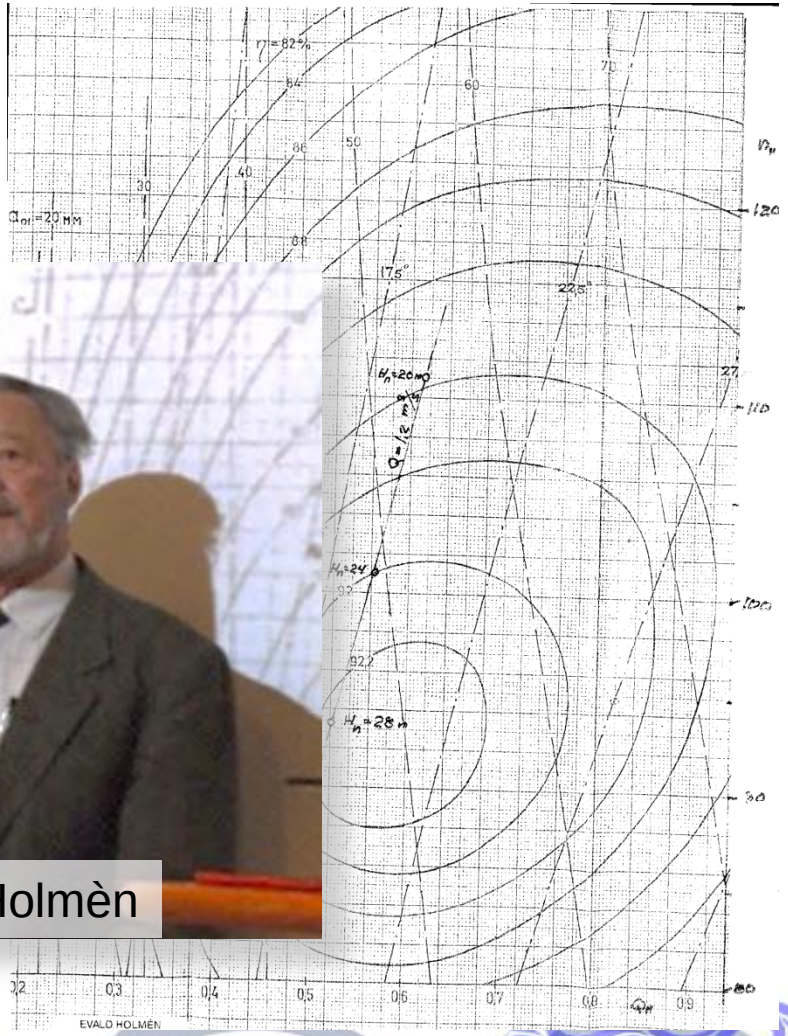
On the inside

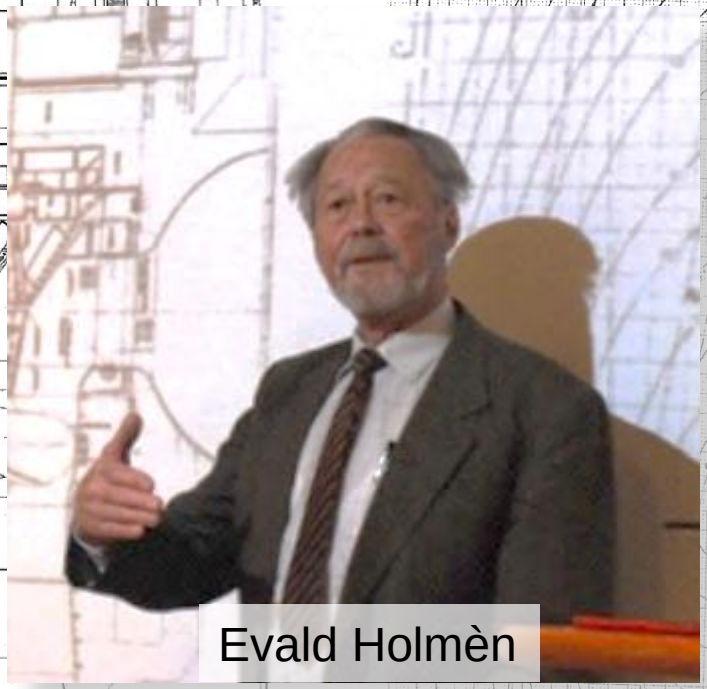


Hydrodynamic design / turbine

- Traditional single regulated kaplan turbine
- Runner wheels were model tested at Nohab (Sweden) in the 60's and 70's

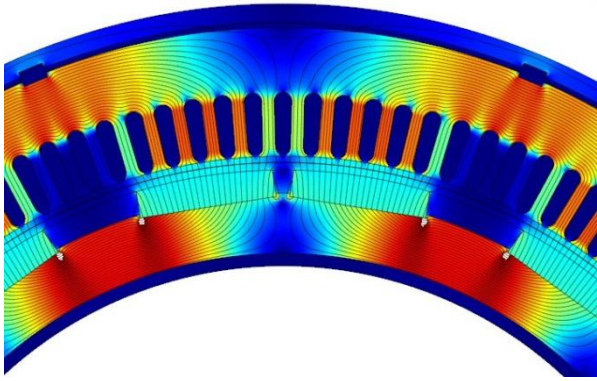


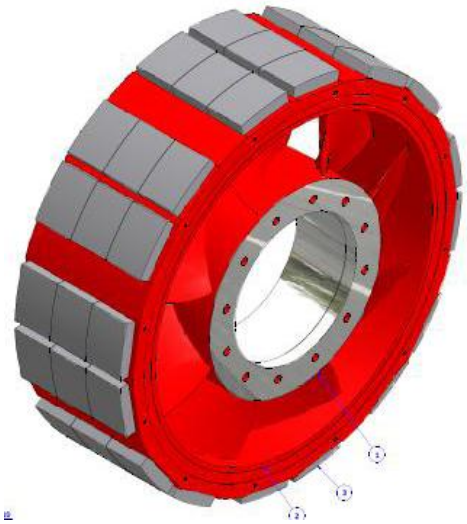


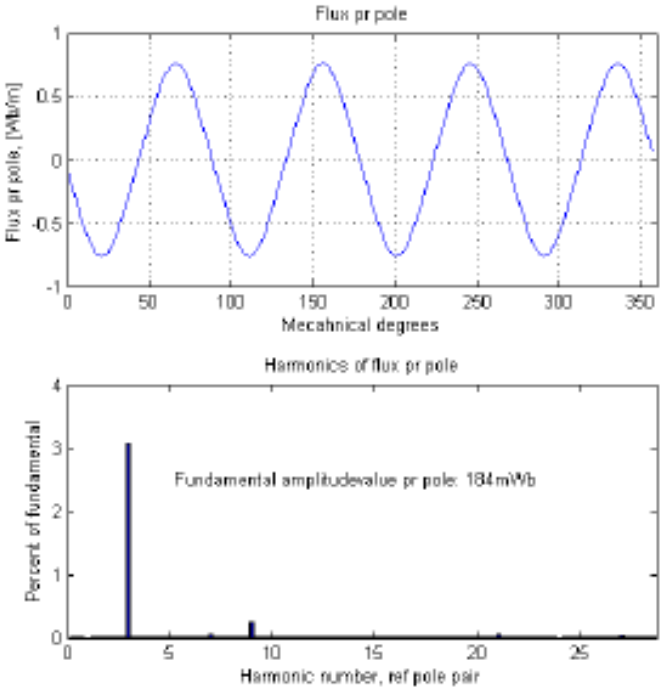


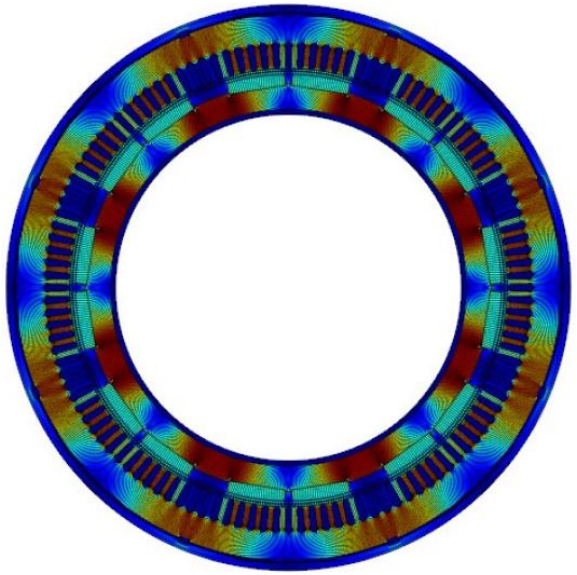
Generator

- Generator design: CleanPower AS
- Permanent magnetized, synchronous
- Rotor yoke on at the rim of runner wheel
- Adapted to site: Pole number, grid frequency, power
- Direct-to-grid connection (via switching and protection gear)






Flux pr pole
Flux pr pole, [Wb/m]
Mecahnical degrees
Harmonics of flux pr pole
Percent of fundamental
Fundamental amplitudevalue pr pole: 184 mWb
Harmonic number, ref pole pair

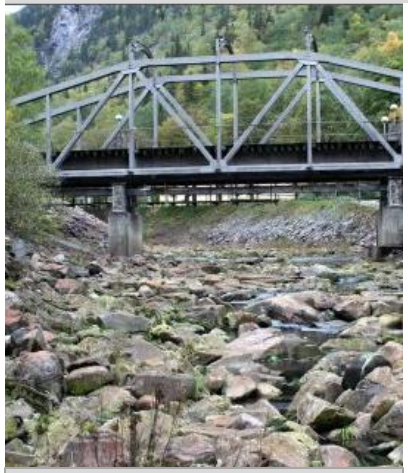


Growing market: Enviromental flow releases

European Union
Water Framework Directive of 2000

- Implemented by 2015
- Increased environmental releases, also from existing dams
- "Opposes" the Renewable Energy Directive, under which Europe shall increase renewables by 20% within 2020
- Increased environmental flows implies lost energy

Conflict of interest:



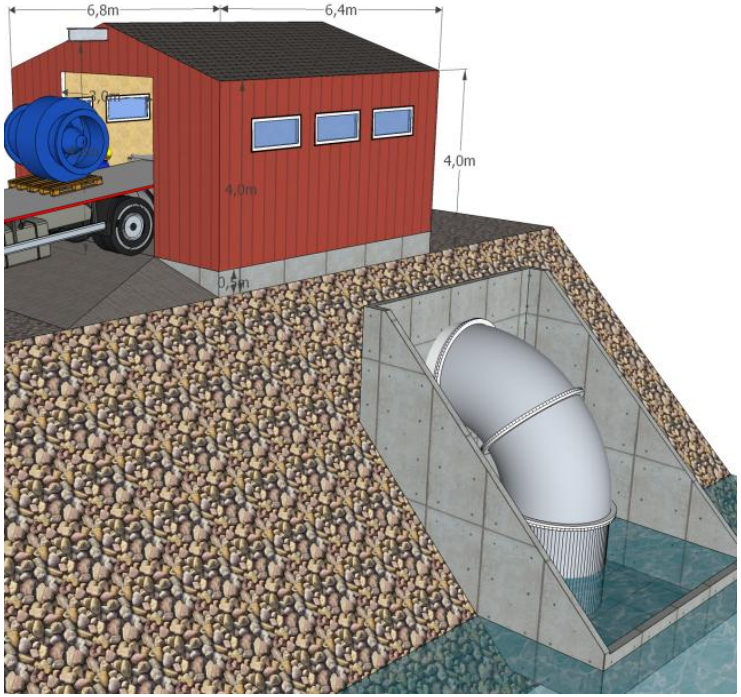
Inadequate flow = dead rivers

High flow = lost energy

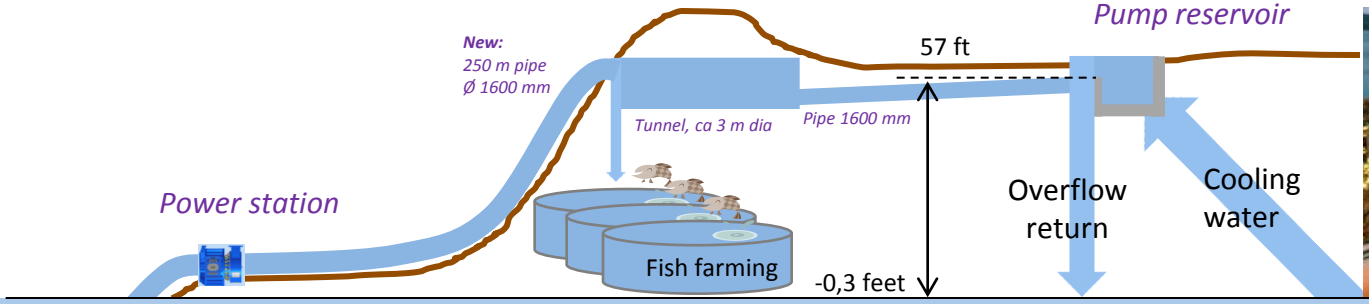
Estimated loss
3% of the European hydropower
16,5 TWh / year lost

→ Market opportunity!

Tjeldbergodden: Industrial energy recovery



- Energy recovered from Statoil methanol plant cooling water pumps
- Produced power will be delivered locally to on-site fish farming installation
- Production: 3.3 GWh/year equivalent to annual consumption of Norwegian 165 households
- 800 000 USD public investment support
- Ongoing project, in operation during 2012.



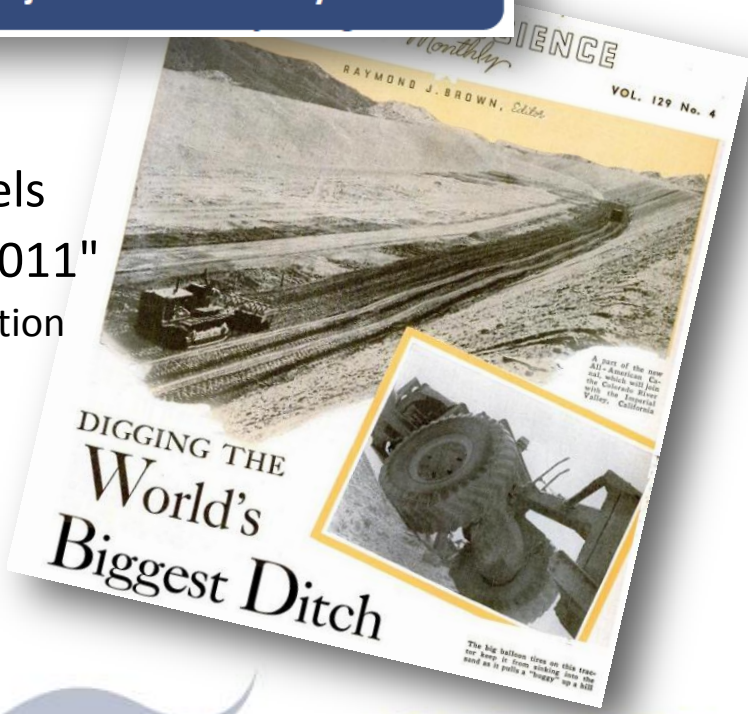
Methanol plant

Huge US opportunities

NHA National Hydropower Association

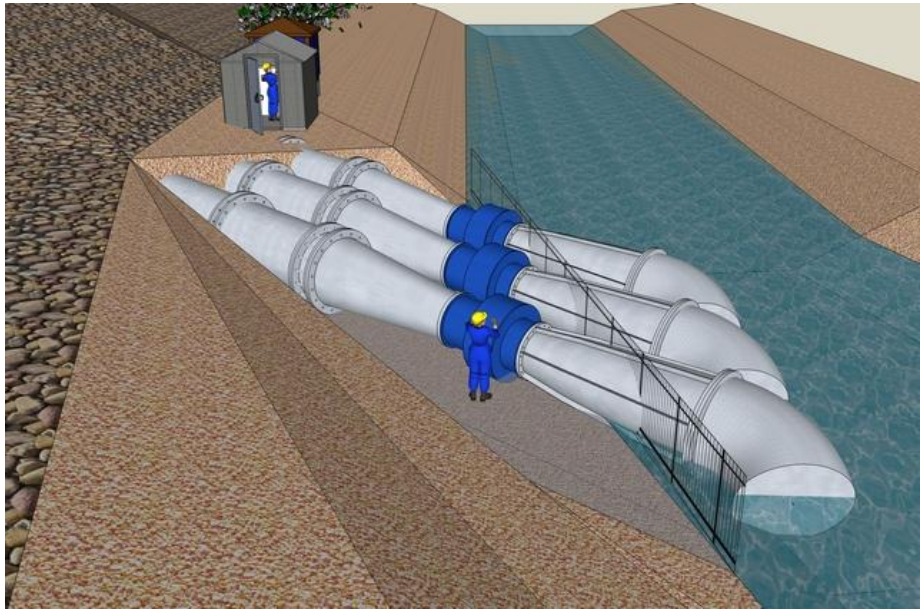
Only 3% of the nation's 80,000 dams generate electricity. Converting existing non-powered dams is key to doubling hydropower and creating 1.4 million cumulative jobs in the next 15 years.

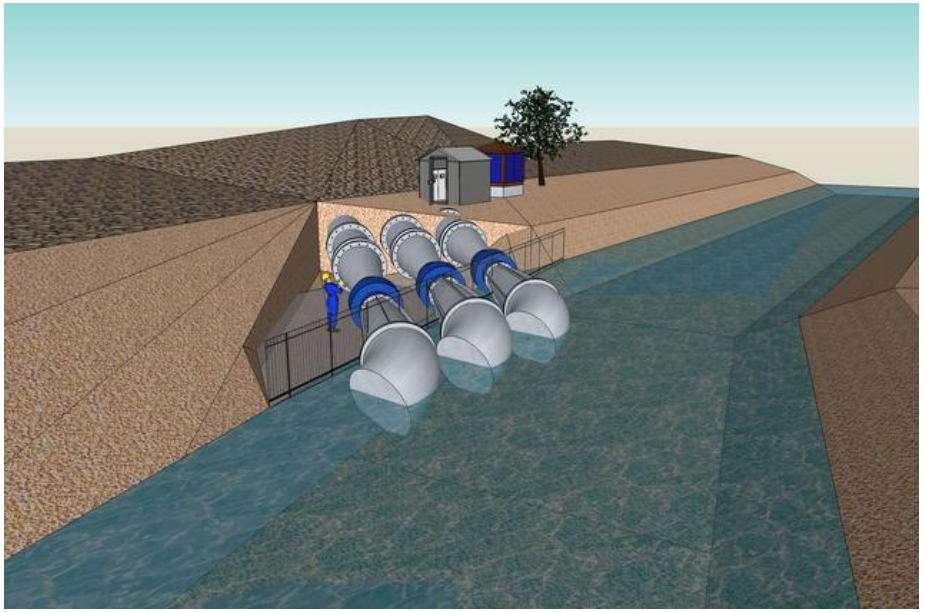
- USA and south-western Canada:
  An extensive network of artificial water channels
- March 2011: "Hydropower Improvement Act 2011"
  - R&D-funding, investment grants, simplified administration etc
  - Technology focus on small low-pressure turbines



US contract

- CleanPower will deliver three 1 MW Turbinators to the '45 mile Hydro' project, for installation on an irrigation channel in Oregon.
- Installation and start-up 2012/2013
- Partially financed through Norwegian "EXIM bank" (Eksportfinans / GIEK)

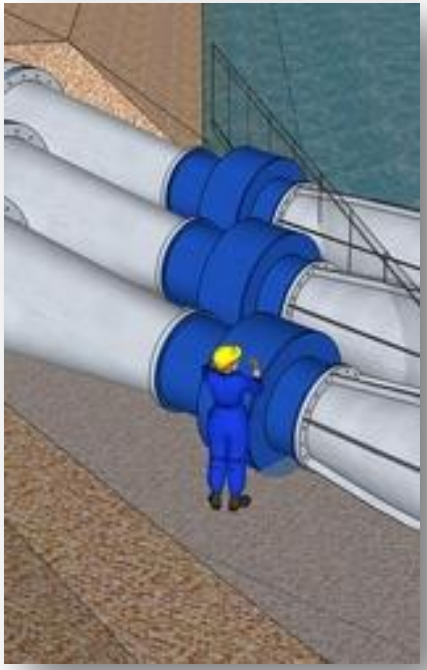




(Very early stage sketches)

Proven technology

International attention



US project = international commercial breakthrough

CleanPower Turbinator™ facilitates small hydro power plants

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